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NOTES ON MATERIALS AND CONSTRUCTION TECHNIQUES BATH-HAVERHILL COVERED BRIDGE BATH, NEW HAMPSHIRE to HAVERHILL, NEW HAMPSHIRE

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August 21, 2002

The following notes are based on an inspection of the Bath-Haverhill Bridge on Saturday, August 17, 2002. The purpose of the inspection was to ascertain the amount of original fabric in the bridge, to study original construction methods, and to develop a sense of preservation priorities in the rehabilitation of the bridge. This inspection followed an arson attempt on the bridge, so the Haverhill police were notified of the inspection.

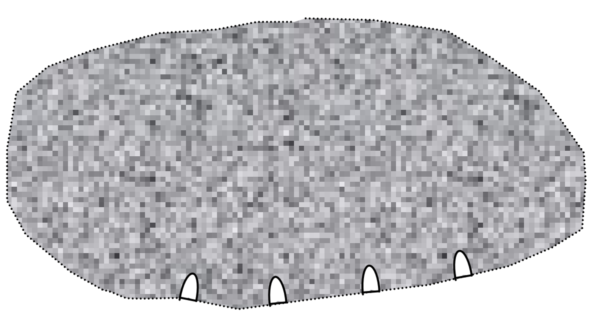
Summary: The Bath-Haverhill Bridge was built in 1829. It has thus far been documented in Brian Pfeiffer, National Register nomination (1974); in Hoyle, Tanner & Associates, "Engineering Study: Haverhill-Bath Covered Bridge, NHDOT Bridge No. 072/063, NH Covered Bridge No. 27, World Guide No. 29-05-04, Haverhill-Bath, New Hampshire" (June 2002); and in Joseph D. Conwill, "Historic American Engineering Record, Bath-Haverhill Bridge, HAER No. NH-33" (July 2002). The following remarks will augment these studies with further observations made from the standpoint of an architectural historian.

The Bath-Haverhill Covered Bridge is the oldest Town lattice truss span remaining in the United States, and one of the oldest covered bridges to survive in the nation. It was built within nine years of Ithiel Town's first patenting of his lattice truss and, as Joseph Conwill has shown, the town of Bath was required to pay a royalty or a penalty for the use of Town's patent. The bridge was the first and remains the only span at this crossing between Bath and Haverhill (Woodsville), New Hampshire.

The Bath-Haverhill Bridge is a remarkable engineering document of the late 1820s. Its substructure, composed two split granite abutments and one split granite pier, all standing on ledge, retains the flat-wedge splitting marks that are characteristic of granite quarrying before about 1830. Its superstructure retains a very high percentage of sawn lattice, chord, floor and roof members, all sawn from eastern white pine (*Pinus strobus*) on a water-powered upright or reciprocating sawmill. The framing techniques employed in the superstructure share certain characteristics with building frames of the same period. To compensate for irregularities in the planking that composes the bridge, a limited amount of hewing was employed to trim planks. To provide regular seats for rafters, tie beams, and diagonal wind braces, the carpenters borrowed techniques from the "square rule" method of framing, which had been newly introduced during the 1820s. In this carpentry technique, recessed seats were hewn in the faces of members to which other members are fitted. This ensures that all joints will be uniform and equidistant from reference lines despite surface irregularities in the intersecting timbers. The use of "square rule" framing has not previously been identified in a bridge.

Substructure: The substructure of the Bath-Haverhill Bridge is composed of two abutments of split granite, laid dry and not hammered to a true bed or face, and a central pier of the same material. Each of the three bridge supports stands on a bed of ledge that extends across the Ammonoosuc River at this point. During low water conditions, the northern or Bath abutment can be inspected along its full height, down to the underlying ledge. The southern or Haverhill abutment is partly submerged by the impoundment of a dam that extends diagonally across the river from the Bath side, intersects the central pier, and continues beneath the bridge at a different angle to a spillway and to a small hydroelectric plant on the Haverhill shore. The northern and western faces of the central pier can be inspected from the ledges below the dam on the Bath side of the river. The central pier has been pointed with mortar, much of which has fallen out of the joints over the years.

Many stones in the Bath abutment and the central pier reveal no obvious signs of the technology that was used to split them. A few stones in both the abutment and pier, however, reveal the presence of flat indentations along their edges. These indentations show that the granite was split using flat wedges inserted in narrow, elongated grooves or slots cut into the stone. This method of splitting granite persisted from the introduction of granite splitting technology in the 1770s until about 1830. After 1830, the flat-wedge method was superseded by the use of plug drills, which create a round hole in the stone, and by the use of "plugs and feathers," which are wedges and shims that are shaped to fit into such round holes.



Evidence of flat-wedge splitting, pre-1830, as seen in stones in the north abutment and the central pier

Thus, the abutments and piers of the Bath-Haverhill Bridge reflect a pre-1830 granite-splitting technology. As will be shown below, the carpentry methods employed on the superstructure reflect technologies of the same period. Together, substructure and superstructure compose a single artifact that illustrates pre-1830 construction methods with a remarkable degree of preservation and integrity.

Superstructure: The trusses and floor and roof system of the Bath-Haverhill Bridge have been described in their overall form in both the Hoyle, Tanner and Conwill reports. The comments below discuss details of the carpentry of the bridge and relate those details to new methods of framing that were being employed in buildings during the 1820s. The Bath-Haverhill Bridge is remarkable in illustrating the application to an engineering structure of practices common in architectural carpentry.

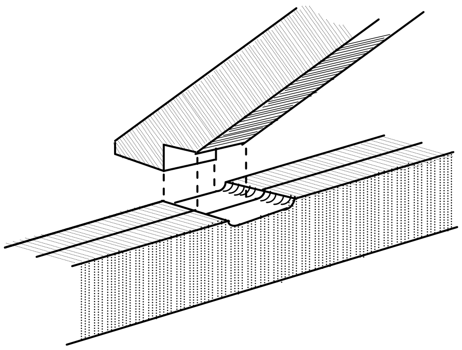
Square Rule Framing: Beginning in the 1820s, carpenters slowly abandoned the age-old method of framing buildings. In the older framing method, used in New England since first settlement, each mortise-and-tenon joint had been fashioned individually. To be certain that the surfaces of intersecting timbers fitted tightly at each joint, carpenters had scribed and chiseled the surface of the tenoned member against the surface of the mortised member. By this technique, the two intersecting surfaces fitted tightly when the tenon was inserted and pinned. This traditional carpentry technique was called the "scribe rule." Because each joint in a scribe rule frame is unique, each of the two intersecting members was marked with the same incised numeral. These numerals ensured that the scribed joints could be assembled properly when the frame was moved from the carpenter's yard to the site where the building was to be erected.

During the 1820s, carpenters moved toward a more standardized framing method. When using the new method, carpenters prepared patterns or templates for each type of joint in a frame, applying these patterns so that all mortises, tenons, pin holes, and other features of joints of the same type would be interchangeable. This method of providing identical and interchangeable joints was called the "square rule."

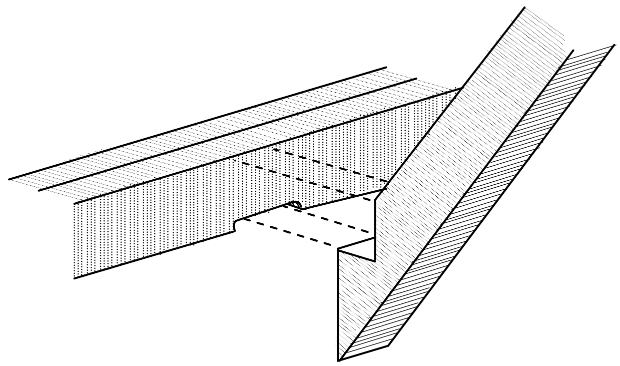
Knowing that the timbers in a building frame might not be of exactly the same width and depth, even if sawn, carpenters applied their patterns with reference to lines drawn on each timber. By this method, each joint bore an identical relationship to others in the frame even if the timbers varied somewhat in their dimensions. Because the joints were uniformly related to reference lines on the timber, square rule framing required no incised numerals to ensure the proper assembly of mated members.

Square rule framing required that the seat of each joint be chiseled down below the irregular surface of the timber so that all seats would be equally distant from the lines drawn on the timber. The result is a noticeable cutting away of the outer surface of the timber at each joint—a clue that the carpenter was using the new, standardized framing method.

Square rule framing generally appeared in New Hampshire buildings during the 1820s. The same period saw an increasing use of sawn rather than hewn timbers in building frames. Sawn timbers did not always preserve a uniform dimension throughout their length, and they often twisted during seasoning, displaying "wīnd." For these reasons, carpenters working with sawn timber frequently employed the square rule method of framing, chiseling seats below the surface of sawn timbers to provide identical intersections for mated members, just as they would have done if working with hewn timber.



Joint between rafter and Chord 1



Joint between wind brace and Chord 2

Introduction of the square rule method of framing coincided with an increasing use of common rafter roofs throughout northern New England. Such roofs often employed simple bird's-mouth joints where the rafters rest on the outer edges of the wall plates of buildings. In contrast to older methods of fastening rafters, these common rafters were often nailed to the wall plates through the V-shaped bird's-mouth cuts, using one or two large spikes.

Framing techniques at the Bath-Haverhill Covered Bridge: It is remarkable that evidence of the square rule framing method is to be seen in the Bath-Haverhill Bridge. Even though the bridge employs sawn planks for its trusses, these planks are not altogether uniform in actual dimensions (see below, *Sawmilling technology*). For this reason, and probably out of habit as well, the carpenters who framed the bridge frequently provided hewn or chiseled seats at the intersection of two members.

Such seats may be seen in some cases where rafters or tie beams rest on the upper surfaces of Chord 1 (above diagram, left side). It is likely, though difficult to verify, that such seats were employed where the floor beams of the bridge rest on Chord 4.

In most cases, recessed seats are likewise seen where the feet of diagonal wind braces bear against the inner sides of Chord 2 (above diagram, right side). In these locations, an inverted, double-spiked bird's-mouth joint holds the foot of the brace against the bottom edge of the chord.

Given the practice of spiking the bird's-mouth joints at the feet of the wind braces to Chord 2, it seems likely that the rafter joints are similarly spiked to the upper edges of Chord 1.

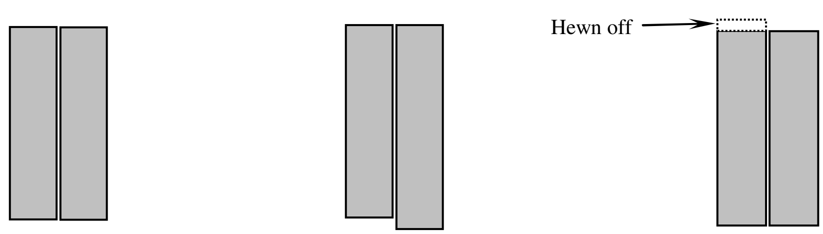
Sawmilling technology at the Bath-Haverhill Covered Bridge: The Bath-Haverhill Bridge employed Ithiel Town's patent, a method of framing lattice trusses. One of the great advantages of Town's patent was its use of uniform, sawn planks, pinned together in a uniform, repetitive pattern, to create a truss as long as might be needed. Proponents of this simplified method of bridge construction reportedly described such trusses as capable of being "built by the mile and cut off by the yard." Indeed, the ends of the trusses at the Bath-Haverhill Bridge do not terminate at vertical posts, but are simply "cut off," with the ends of the diagonal lattice members unattached to anything.

In theory, a multitude of planks of a single dimension were sufficient to build a bridge according to Town's patent. Such planks were pinned together at uniform angles to create the lattice, and others of the same type were pinned horizontally at the tops and bottoms of the lattice to create the upper and lower chords of the truss.

In the Bath-Haverhill Bridge, the standard plank dimension is 3" by 10." All original planks seen in the bridge trusses, including those of the upper and lower chords, conform roughly to this dimension. All were sawn in upright or reciprocating water-powered sawmills.

In actuality, the average dimension of the truss planks seems to be about 3" by 9½." Some planks measure as much as a full 10," but many do not. The irregularity of plank widths may probably be attributed to inaccuracy in original sawing (see below), and also to shrinkage across the grain during seasoning.

In some cases, the planks that were paired to make elements of upper chords were mismatched in width. If it was important that the edges of these paired planks be even, as where rafters rest on the tops of the uppermost chords, the projecting edges of the wider planks were carefully hewn off (right diagram, below). In other cases where it did not matter, the paired planks were made even at top or bottom, but allowed to have staggered edges on the opposite side (middle diagram, below).



Well-matched planks *Poorly-matched planks* *Planks hewn to an even edge*

The difficulties of obtaining uniform planks from local sawmills may reflect the imprecision with which reciprocating sawmills normally produced lumber. Since the Bath-Haverhill Bridge was built in an age when carpenters often reworked rough lumber with planes and other finishing tools when they needed uniform dimensions or finished surfaces in a building, the production of planks of perfect uniformity was perhaps not demanded or expected of sawmill operators.

The New Hampshire law regarding sizes of boards and planks that was in effect in 1829 had been passed by the legislature in 1785. It stated that "no pine boards shall be shipped for exportation to a foreign market but such as are square edged, and *not less* than one inch in thickness [italics added]." Regarding plank thickness, the law stated that "the standard for the thickness of merchantable plank shall be two inches; and when any shall be purchased for particular use, of different thickness, it shall be admeasured and calculated by that standard." [1] This law implies that every merchantable board or plank of a given nominal thickness was required to have at least the thickness cited. The law does not forbid sawing boards or planks somewhat thicker than the nominal dimension, and some of the planks used in the truss webs and chords of the Bath-Haverhill Bridge are somewhat over three inches in thickness. As with the varying width of the planks in the trusses, this variation in thickness appears to have been unintentional but within tolerances that were acceptable at the time.

One remarkable feature of the Bath-Haverhill Bridge is the degree to which original planking has survived throughout the structure. Except where the eastern truss was damaged by a floating tree in the flood of 1927, there are few places where 3" by 10" planks, showing the distinctive marks of the reciprocating saw, are not found throughout the structure. Indeed, even the bottom chords (Chords 3 and 4), most exposed to spray from the dam below, show this evidence of great age in those areas where they can be observed.

It was possible to examine one floor joist or beam at close range at the central pier of the bridge. Although covered with friable, fuzzy wood fibers raised by road salt and moisture, this beam proved to be very sound and to reveal the marks of a reciprocating sawmill. Although it was impossible to examine other joists as closely, their appearance when seen from below suggests that many of these members are similarly sawn, and so may be very old if not original to the bridge.

As noted by Joseph Conwill in his report, most of the bridge's floor joists appear to have been hewn on their bottoms. Although these timbers could have begun as logs that were hewn to a single flat surface before first being run through a sawmill, they could also derive their rough-hewn bottom surfaces from a more recent attempt to chop away the fuzzy fibers that may have formed on their undersides.

It is remarkable that almost all of the tie beams, upper lateral bracing, and rafters of the bridge also show evidence of having been sawn on an upright saw. The same is true of most of the roof sheathing boards, which run longitudinally from rafter to rafter; only the roof sheathing close to the eaves of the bridge reveals a large proportion of replaced boards. The majority of diagonal wind braces, which link the rafters to the tie beams and to the bottom of Chord 2, have been replaced due to breakage from truck impact or to the insertion of the arches in the bridge, yet a few upright-sawn originals remain. In such cases, the diagonal wind braces are pinned to the tie beams and rafters with square or square-headed wooden trunnels.

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[1] *The Laws of the State of New-Hampshire*. Hopkinton, N.H.: Isaac Long, Jr., 1830. Title L: "Admeasurement and Size of Lumber," Chapter I, pp. 212-216.

Although a closer survey of the bridge may reveal more new wood than was apparent in our inspection, it appears that the Bath-Haverhill Bridge retains a percentage of original materials that would be considered high even in a surviving dwelling of 1829. This is doubly remarkable because the bridge is exposed to harsh and damp environmental conditions and traffic impacts, and because it is one of the oldest wooden bridges in the United States. The high proportion of surviving original fabric, combined with unexpected evidence of framing techniques of the 1820s that have not previously been noticed in a bridge, make the Bath-Haverhill Bridge a remarkable and valuable monument in the history of American engineering.